

Specification for

Sulphur hexafluoride for electrical equipment

UDC 621.31:546.226'161

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This British Standard, having been approved by the Electrical Industry Standards Committee, was published under the authority of the Executive Board on 30 September 1975

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The following BSI references relate to the work on this standard:
Committee reference
ELE 115
ELE 115/3
Draft for comment 71/29873

ISBN 0 580 08643 7

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

	Page
Co-operating organizations	Inside front cover
Foreword	ii
1 Scope	1
2 References	1
3 Description	1
4 Impurities	1
5 Sampling	1
6 Size of cylinders	1
7 Marking of cylinders	1
8 Certificate of compliance	1
Appendix A General information concerning sulphur hexafluoride	2
Appendix B Sampling technique	3
Appendix C Identification of gas	4
Appendix D Toxicity	4
Appendix E Water content and condensation temperature	5
Appendix F Carbon tetrafluoride, oxygen and nitrogen	11
Appendix G Hydrolysable fluorides	15
Appendix H Acidity	16
Appendix J Mineral oil content	18
Figure 1 — Saturated vapour pressure curve for sulphur hexafluoride	2
Figure 2 — Gravimetric determination of water in sulphur hexafluoride gas	12
Figure 3 — Main features of dew-point cell design	13
Figure 4 — Arrangement for measurement of dew point	14
Figure 5 — Example of chromatogram obtained when determining oxygen, nitrogen and carbon tetrafluoride	14
Figure 6 — Apparatus for determination of free acidity	17
Figure 7 — Gas washing bottle for separation of oil from sulphur hexafluoride gas	20
Figure 8 — Apparatus for separating oil from sulphur hexafluoride gas	20
Table 1 — Concentrations of impurities	1
Table 2 — Hygrometric data for uncontaminated water vapour	10
Publications referred to	Inside back cover

Foreword

This British Standard has been prepared under the authority of the Electrical Industry Standards Committee. Sulphur hexafluoride is used for insulation, cooling and arc interruption in electrical equipment. Impurities resulting from manufacturing and handling operations are invariably present and need to be limited to quantities that will avoid hazards to equipment or personnel. The standard is largely concerned with specifying maximum levels of impurities and associated methods of test for impurities in sulphur hexafluoride when this substance is supplied for electrical uses. It applies only to sulphur hexafluoride before the substance has been introduced into any electrical equipment. After use in equipment, the types and levels of impurity and the circumstances under which tests are carried out may be different. Other appropriate test methods and practical information are considered in BS 5209, *“Code of practice for the testing of sulphur hexafluoride taken from electrical equipment.”*

The present standard is based on IEC Publication 376, *“Specification and acceptance of new sulphur hexafluoride”* except so far as the permissible levels of oxygen and nitrogen are concerned. The IEC Publication groups these impurities together, specifying a permissible total quantity of “air”. This standard, however, sets separate limits for oxygen and nitrogen, together with a suitably modified test procedure because it is the oxygen in the air which is to be avoided whereas the nitrogen is generally only a harmless diluent.

Many operators handling the substance may be unfamiliar with its properties. It has thus been thought desirable to include, in Appendix A, brief details of these properties; more extensive and definitive physical, chemical, thermal and electrical data are to be included in an IEC Publication at present in course of preparation. Special sampling techniques are required and these are detailed in Appendix B.

Attention is particularly drawn to the final paragraphs of Appendix A. Sulphur hexafluoride at normal temperatures and pressures is a dense, invisible, odourless vapour which will not support life; these paragraphs warn against the resulting dangers which may arise in confined spaces. In certain circumstances section 30 of the Factories Act 1961 could apply; paragraph 9 may be particularly relevant.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies requirements and methods of test for sulphur hexafluoride as supplied for use in electrical equipment.

2 References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3 Description

The material supplied shall consist essentially of sulphur hexafluoride, SF₆.

NOTE This identity may be verified either by examining the infra red absorption spectrum or by a density determination (see Appendix C).

4 Impurities

The material complying with the requirements of this standard shall not contain more than the stipulated concentrations of impurities as shown in Table 1 when tested by the methods shown.

Where a purchaser wishes to specify a limit for condensation temperature, in addition to or in substitution for the water content requirement, this may be done by agreement with the supplier. In the absence of such an agreement, the gravimetric method of determining water content shall be used for referee purposes. (See note 2).

NOTE 1 Appendix D describes a biological method of test for toxic impurities. It is essential that biological tests are carried out by a properly competent organization (with Home Office certification) employing suitably experienced personnel. Thus it will usually not be possible for purchasers of sulphur hexafluoride to carry out their own tests for toxic impurities and purchasers are advised to require, under the provisions of clause 8, a certificate from their suppliers, that the material is non-toxic when tested by the method described in Appendix D.

Table 1 — Concentrations of impurities

Impurity or group of impurities	Maximum permitted concentration by mass	Test method	Note
Toxic impurities	passes test	Appendix D	1
Water	15 mg/kg	Appendix E	2
Carbon tetrafluoride	0.05 %	Appendix F	
Oxygen	0.01 %	Appendix F	
Nitrogen	0.04 %	Appendix F	
Hydrolysable fluorides (as hydrofluoric acid)	1.0 mg/kg	Appendix G	
Acidity (as hydrofluoric acid)	0.3 mg/kg	Appendix H	
Oil	10 mg/kg	Appendix J	

¹⁾ 1 mbar = 10² N/m² = 100 Pa

NOTE 2 Appendix E describes two methods by which water content may be assessed. The first is a gravimetric method which is specific to water but is difficult and laborious. The second method determines the condensation temperature (dew point) of impurities in the gas; strictly speaking, this does not specifically determine water since water-soluble impurities in the sulphur hexafluoride may appreciably raise the condensation temperature for a given water content. However, for the impurity levels allowed for new sulphur hexafluoride this effect is small, and since the condensation requirement is the more stringent, if the sulphur hexafluoride meets the appropriate condensation temperature limit (− 40 °C at 1 013 mbar¹⁾) its water content will be within the required limit.

5 Sampling

Samples of liquid sulphur hexafluoride for analysis shall be taken in accordance with Appendix B.

6 Size of cylinders

Sulphur hexafluoride shall be supplied in steel cylinders preferably of either 10 litres or 40 litres nominal volume.

The design and construction of the cylinders shall comply with the requirements of BS 401 or BS 5045-2. The filling ratio shall comply with the requirements of BS 1736. The mass of sulphur hexafluoride contained in each cylinder shall be stated. The cylinder valve outlets shall comply with the requirements of BS 341-1:1962, Outlet No. 8.

NOTE Cylinders coming from Europe will usually have an outlet complying with the requirements of IEC 376. The nut and connector for the No. 8 outlet specified in BS 341-1:1962 is not designated for sulphur hexafluoride in that standard. However this nut and connector taken together will satisfactorily mate with the IEC valve outlet and vice versa.

7 Marking of cylinders

Each cylinder shall be legibly marked at the valve end and preferably away from the cylindrical part of the body with:

- a) the symbol SF₆;
- b) the words sulphur hexafluoride;
- c) the tare mass of the cylinder without protective cap.

8 Certificate of compliance

The supplier shall, if required, certify that the material complies with the requirements of this standard.

Appendix A General information concerning sulphur hexafluoride

Sulphur hexafluoride, SF_6 , is an inert, non-flammable, non-toxic, odourless and colourless substance. At normal temperatures and pressures it is a gas, but it may readily be liquefied by compression (below the critical temperature of 45.6°C) and it is normally transported as a compressed liquefied gas in steel cylinders. The saturated vapour pressure curve is shown in Figure 1.

The gas is electronegative (i.e. it tends to attract free electrons) resulting in high electric strength and good arc-quenching properties; this makes it of value as an insulant or arc-extinguishing medium in circuit breakers, transformers, enclosed busbar systems, etc. The electric strength depends on the conditions of use, but normally is two to three times the electric strength of nitrogen; this electric strength is very little affected by moderately small quantities of nitrogen, air, or other impurities mixed with the sulphur hexafluoride.

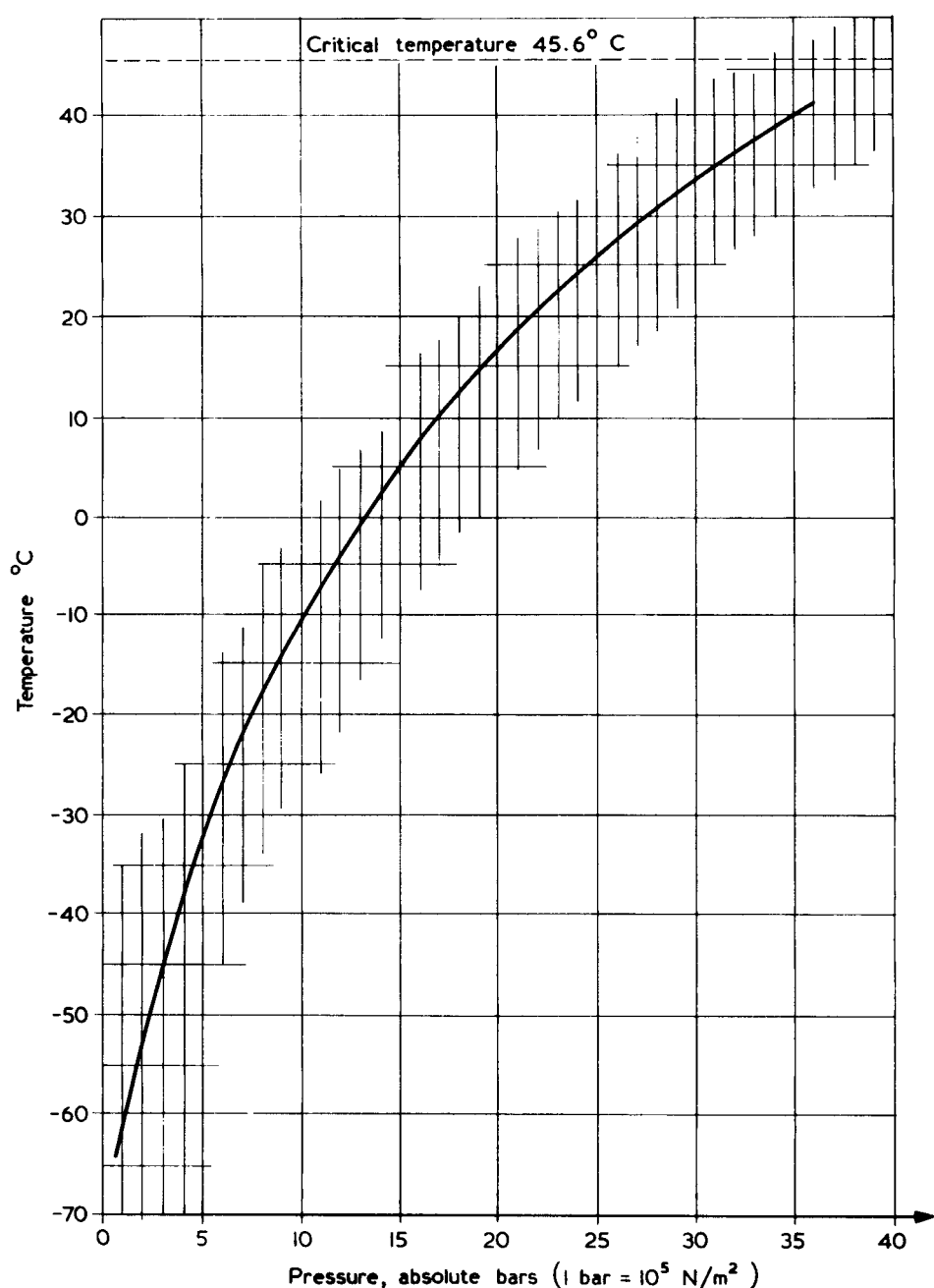


Figure 1 — Saturated vapour pressure curve for sulphur hexafluoride

Pure sulphur hexafluoride is chemically inert and, at temperatures up to about 180 °C, its compatibility with materials used in electrical equipment is similar to that of nitrogen. Impurities, particularly acidic impurities, water and oxygen, may give rise to corrosion, condensation, or other difficulties; but while impurity levels remain within the limits set by this specification, such trouble is unlikely. (See BS 5209 for conditions that may arise when the gas is in use.)

Pure sulphur hexafluoride is non-toxic, but certain impurities which might be present are very toxic in concentrations so small that physical or chemical tests would be impracticable. A biological test is used (see Appendix D) to ensure that new sulphur hexafluoride contains only harmlessly small quantities of such impurities.

Sulphur hexafluoride gas is very dense (6.16 kg/m³ at 20 °C and 1 013 mbar²⁾, that is, about five times denser than air). This high density has its advantages; for example, it is possible to fill some laboratory equipment sufficiently well by simple displacement of air. However the high density also gives rise to a serious potential danger; equipment, trenches, and similar enclosed spaces may remain full of the gas, which has no colour or odour which might warn personnel of this fact.

Although sulphur hexafluoride is non-toxic it will not support life, and personnel entering a sulphur hexafluoride-filled enclosure, trench, etc. will be asphyxiated. It is essential that personnel be made aware of this danger, and that equipment, etc. is adequately ventilated before being entered.

Appendix B Sampling technique

B.1 General

Sulphur hexafluoride is normally supplied under pressure in cylinders so that most of the substance is liquid, with a small proportion in vapour form above the liquid; impurities are present in both phases but in differing proportions. Samples should be taken from the liquid phase, so that they are representative of most of the substance in the cylinder, by tilting or inverting the cylinder so that the outlet is at the lowest point.

B.2 Sample line and connection

It is preferable for samples to be passed directly from the supply cylinder to the analysis equipment; a sample line is required for this purpose. The sample line serves primarily to vaporize the liquid sulphur hexafluoride coming from the cylinder, and may also conveniently incorporate a fine-control needle valve since it is often difficult to control flow by means of the cylinder valve alone. The sample line assembly would thus consist of the following components.

B.2.1 Fine control valve (optional). An all-metal fine-control needle valve or all-metal pressure reducing valve, screwed directly onto the outlet of the cylinder valve or connected to it by a short length of stainless steel tubing similar to the sample line itself (see **B.2.2**).

NOTE It is essential that the portion of the system connected to the cylinder is suitable for working at pressures that may occur in the cylinder, that is, up to about 40 bar³⁾.

WARNING. The cylinder valve and needle valve should never be left closed at the same time with liquid sulphur hexafluoride trapped between them, as a rise of temperature is likely to lead to an explosion.

B.2.2 Sample line. The sample line should consist of approximately 2 m of stainless steel tubing of approximately 3 mm internal diameter. One end is fitted by means of a metal connector to the fine-control valve (or directly to the outlet of the cylinder valve, if no fine-control valve is used); the other end is connected without valves or other restriction to the analysis apparatus.

B.2.3 Joints. To make gas-tight threaded joints, polytetrafluoroethylene tape is permissible, but a grade containing no plasticizer should be used, otherwise there is a risk of introducing impurities into the sample. Permanent metal-to-metal joints in the sample line assembly are to be brazed or soldered (afterwards being cleaned of flux) or another type of all-metal (e.g. compression) joint may be used.

At the analysis apparatus, the butt-joint technique described in **E.2.5** is suitable.

B.2.4 Use of sample line. To vaporize the liquid from the cylinder, it may be necessary to warm the sample line slightly. This warming may be by a heating tape or by a small hot-air blower. The line may be coiled for ease of handling.

Purge the sample line by a gentle flow of sulphur hexafluoride for several minutes immediately before a test.

²⁾ 1 mbar = 10² N/m² = 100 Pa

³⁾ 1 bar = 10⁵ N/m² = 100 kPa

B.3 Intermediate sample cylinder

If it is impossible to take gas from the supply cylinder and pass it directly into the analysis equipment, it may be necessary to use an intermediate sample cylinder which should be of a non-reactive metal; stainless steel is suitable.

B.3.1 Filling technique for sample cylinders. Heat the cylinder to 100 °C with its valve open and evacuate it with an oil-sealed rotary pump. Connect the evacuated cylinder to the sulphur hexafluoride container, and, after cooling the cylinder, introduce a small amount of liquid sulphur hexafluoride. Shake the cylinder and vent off the gas. Re-evacuate the cylinder and repeat the washing steps. Introduce into the cylinder the required sample quantity.

NOTE Every effort should be made to ensure that the sample cylinder and associated pipework is maintained in a chemically clean condition to avoid contaminating the sample. Sample cylinders should be kept solely for use with sulphur hexafluoride and when not in use they should be stored filled with sulphur hexafluoride under slight pressure.

WARNING. Intermediate sample cylinders and associated pipework shall withstand a test pressure of 70 bar. A maximum filling ratio of 1.00 kg SF₆ per litre cylinder volume is suggested in temperate climates. It is recommended that the sample cylinder is weighed just before and immediately after filling. A sample of 0.5 kg is generally adequate to complete all tests except toxicity testing.

Appendix C Identification of gas

C.1 General

If there is doubt whether the material supplied is sulphur hexafluoride, identification may be confirmed by the following methods.

C.2 Infra-red absorption spectrum

Where the required apparatus is available, it may be verified whether the gas is sulphur hexafluoride by examining its infra-red absorption spectrum and comparing this with that of gas known to be sulphur hexafluoride.

C.3 Density determination

C.3.1 Principle of method. A known volume of gas is weighed.

C.3.2 Apparatus

A glass bulb or cylinder fitted with vacuum-tight stopcocks at opposite ends. A capacity of about 100 ml is adequate but a larger volume may be used provided a suitable balance is available.

C.3.3 Calibration of the glass bulb. Obtain the volume of the bulb by weighing to ± 0.1 g empty and then full of distilled water at approximately ambient temperature; the difference gives the mass of water and hence the volume of the bulb at that temperature. Obtain the mass of the bulb by evacuating it, then weighing to ± 0.20 mg.

NOTE For borosilicate glasses no further bulb volume correction is required.

C.3.4 Procedure. Cool the bulb to just below ambient temperature and then fill it by purging with sulphur hexafluoride. Allow the filled bulb to attain ambient temperature then open a stopcock momentarily to bring the gas in the bulb to atmospheric pressure. Note the ambient temperature and barometric pressure and then reweigh the bulb.

NOTE Care should be taken to ensure that the bulb is properly filled. It will be so if the bulb is purged for about 1 min at about 5 l/min.

WARNING. In both evacuation and filling with sulphur hexafluoride, proper safety precautions are essential.

C.3.5 Calculation of result

$$\text{Density (kg/m}^3\text{)} = 1000 \frac{m_2 - m_1}{V}$$

where

m_2 is the mass of bulb filled with SF₆ (g)

m_1 is the mass of evacuated bulb (g)

V is the volume of gas in millilitres corrected to reference temperature and pressure (e.g., 20 °C and 1 013 mbar^a) from the temperature and pressure existing at the time the pressure in the bulb was adjusted.

^a 1 mbar = 10² N/m² = 100 Pa

Appendix D Toxicity

It is essential that these tests are carried out by a properly competent organization (with Home Office Certification) using suitably experienced personnel.

D.1 Toxicity test

D.1.1 Experimental details. Five female albino mice, previously maintained under barriered conditions so that they are as free as possible from disease are to be used for each test. They are to be kept under observation for at least 5 days prior to exposure to ensure that they are in good health. They are then to be introduced into the exposure chamber containing an atmosphere of 79 % SF₆: 21 % O₂ (by volume) and kept there for a period of 24 h. During this time, water and laboratory mouse diet are to be supplied ad lib.